CHALMERS UNIVERSITY OF TECHNOLOGY

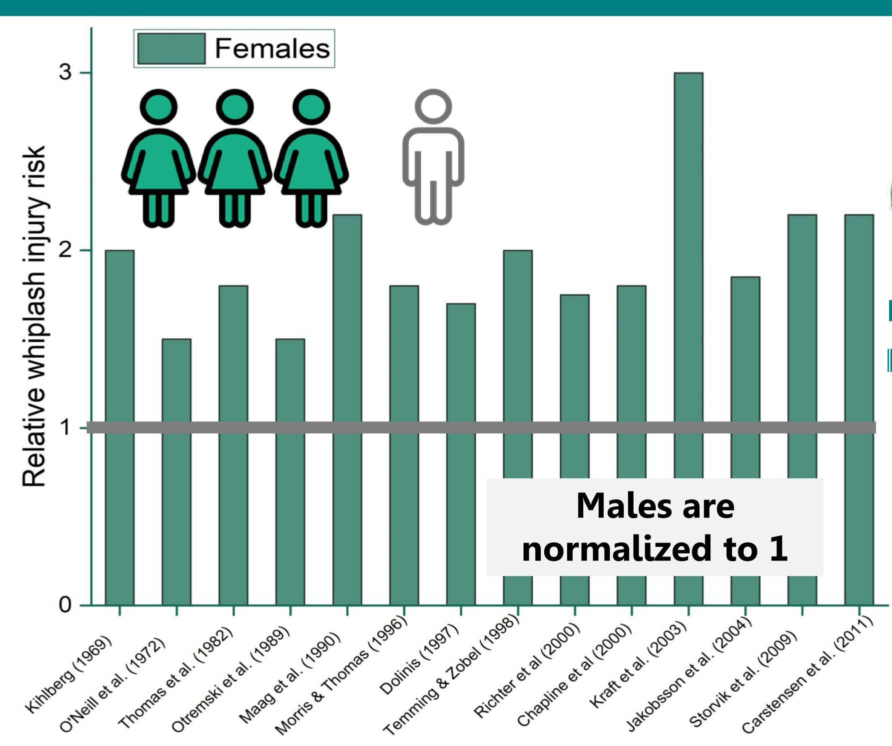
SAFER VEHICLE AND TRAFFIC SAFETY CENTRE AT CHALMERS

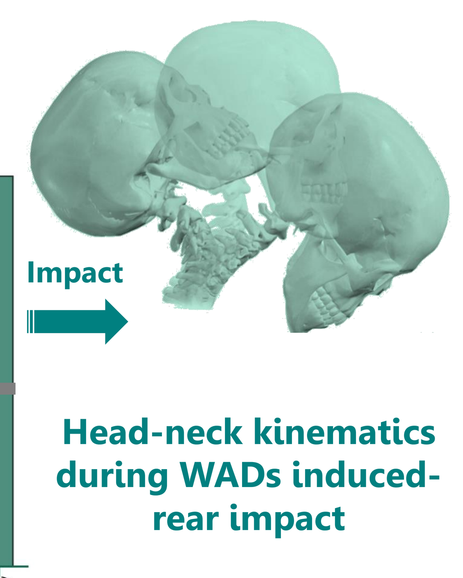
Implementation and Calibration of Active Reflexive Cervical Muscles on Female Head-Neck Model

I Putu A. Putra*, Johan Iraeus, Robert Thomson and Mats Y. Svensson

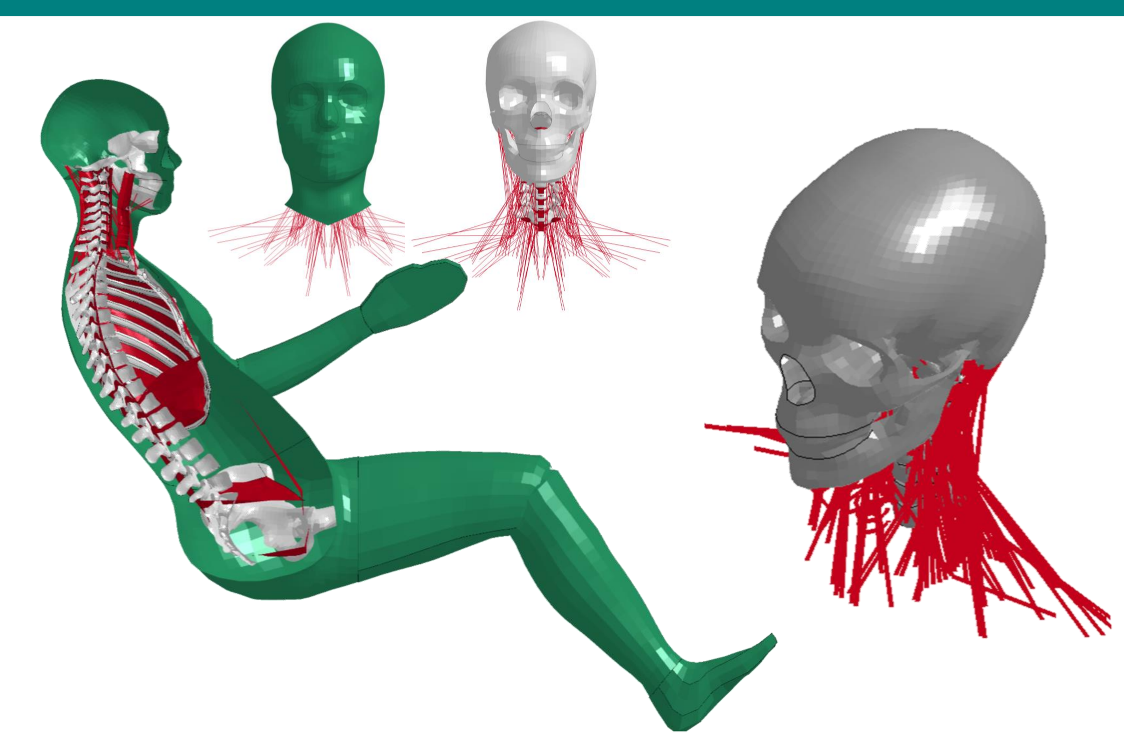
Division of Vehicle Safety, Department of Mechanics and Maritime Sciences, Chalmers University of Technology

1. Background



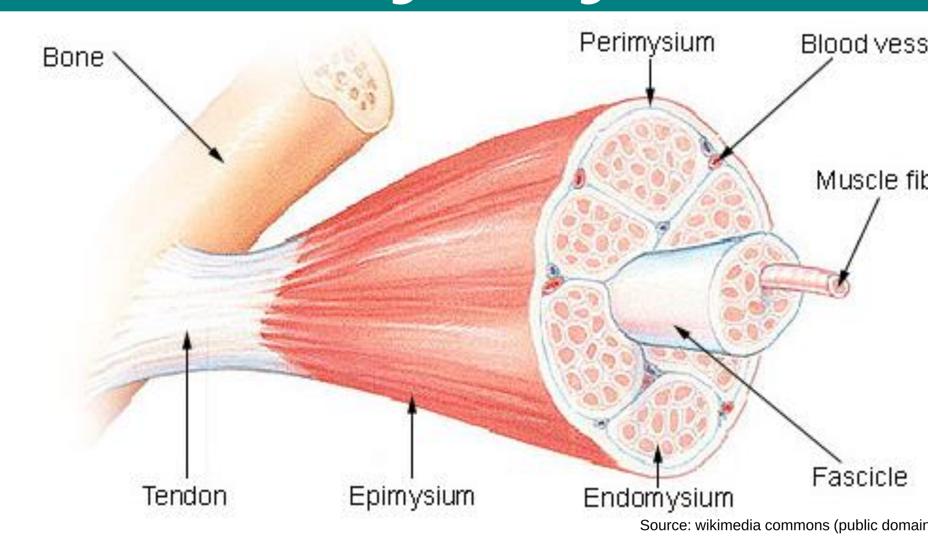


- Whiplash Associated Disorders (WADs) or Whiplash injuries is a worldwide concern due to high number of cases every year [1,2,3].
- The injury mechanism of WADs remains unclear and not fully understood.
- If the WADs are sorted based on sex, females have a risk up to 3 times greater than males [4].



- ViVA OpenHBM is the first open source 50th percentile female HBM. [5]
- HBMs are a tool to study the injury mechanism and kinematics, therefore active muscles responses must be included as studies have shown that muscles influence head-neck kinematics during impact. [6]

2. Study Objectives

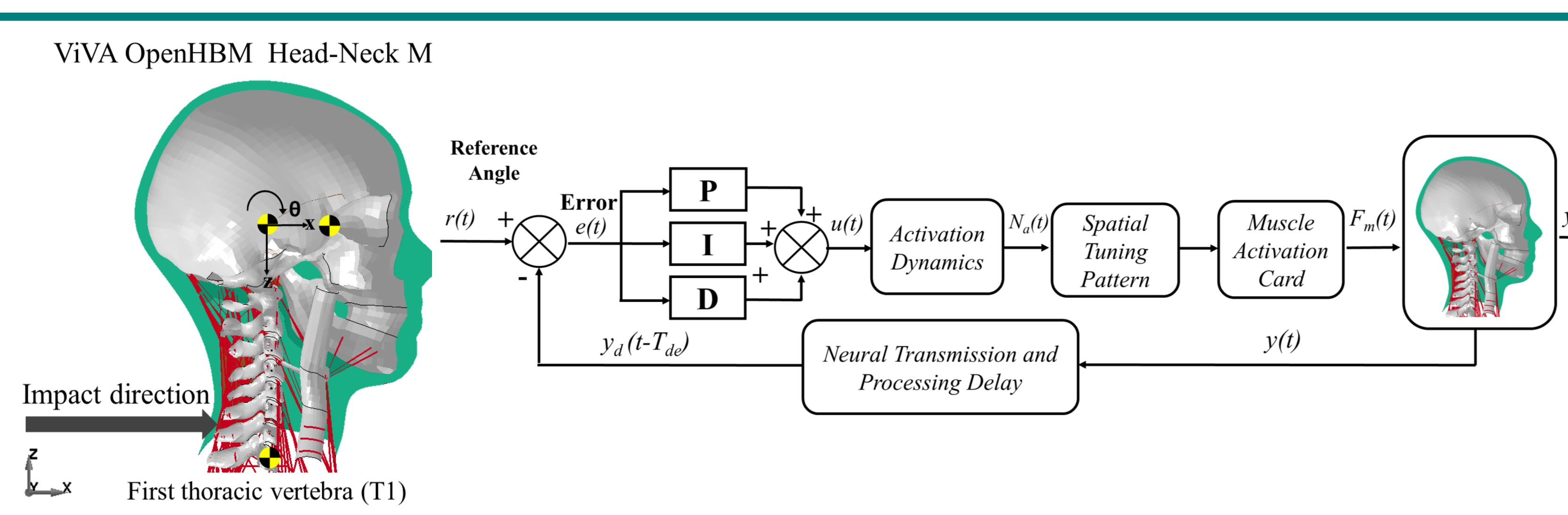


The main goal is to include an active muscle function for improved whiplash kinematics

- To implement and calibrate a Proportional Integral Derivative (PID) feedback control mechanism to the Finite Element models of cervical muscles.
- To analyze the effects of three calibration objectives on the head and cervical kinematics of the model.

3. Method

3.1 Implementation of PID Controller on Female Head-Neck Model [7,8]



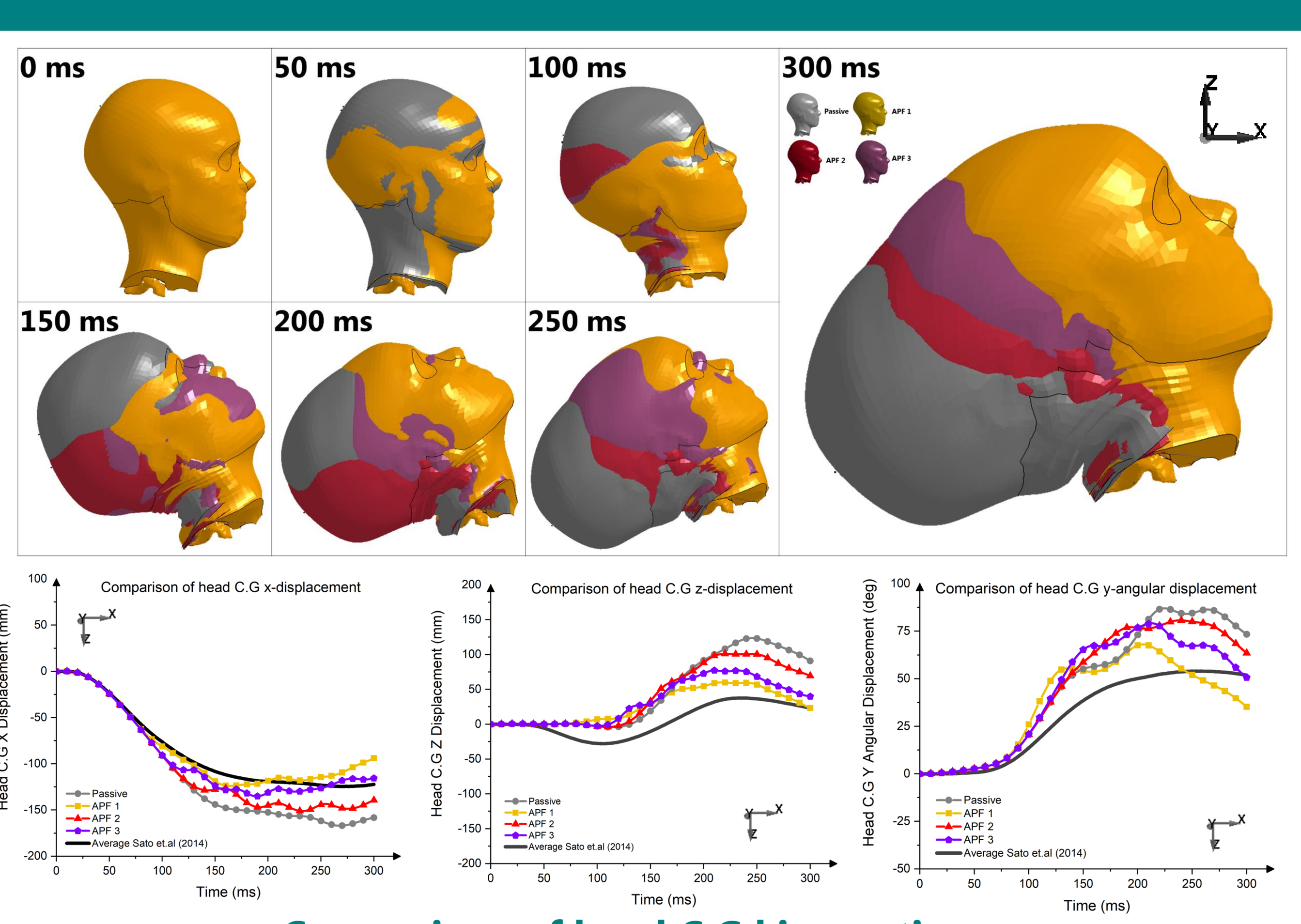
3.2 Calibration Simulation Setup

- LS-Opt was used to calibrate the model [9].
- Volunteer data based on Sato et al. 2014 [10,11].
- Total simulation time 400ms including 100ms of gravity settling.
- T1 kinematics from the volunteer were prescribed on the T1 of the model.
- Objective rating evaluation was conducted using CORA 4.0.4 [12].

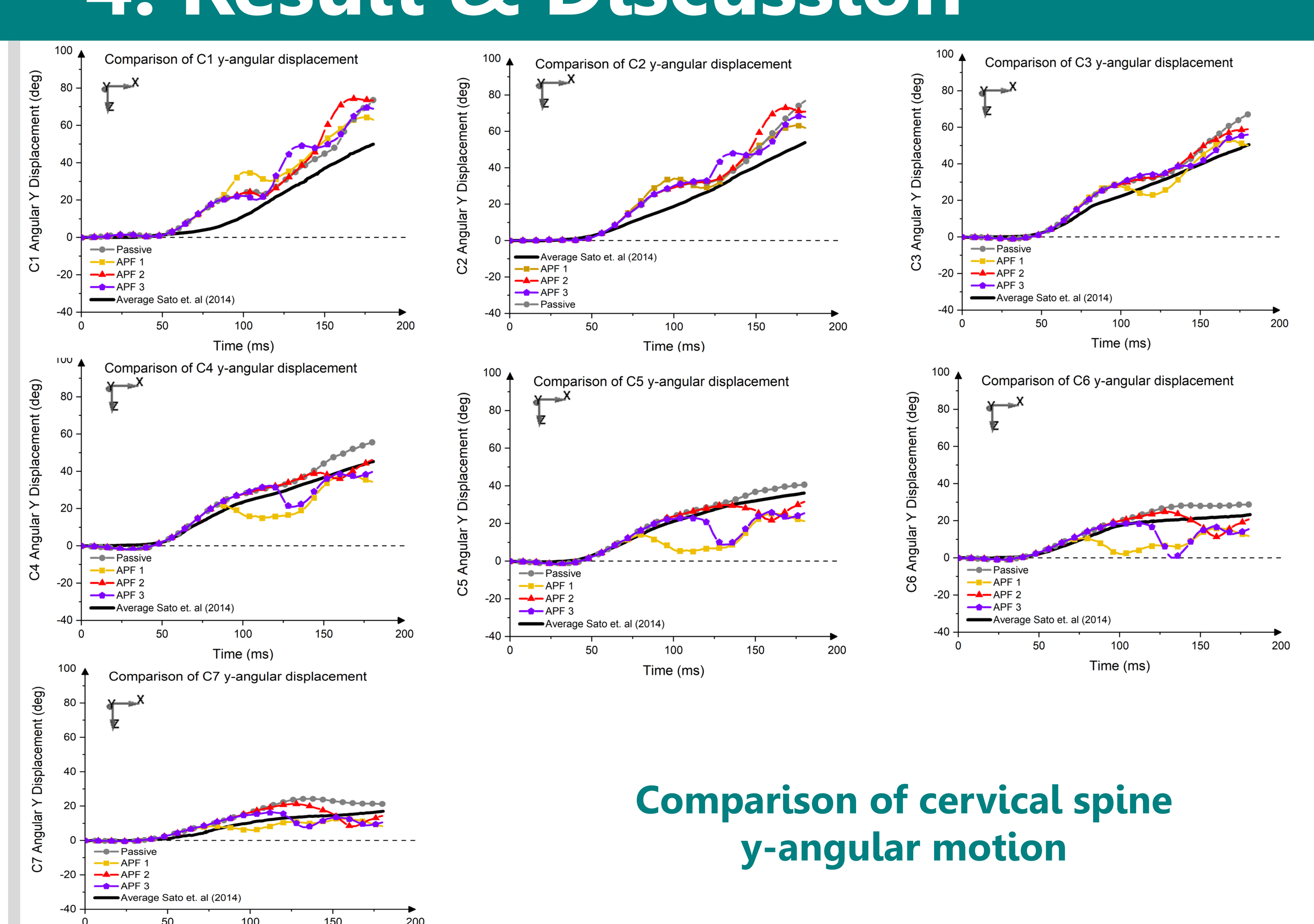
3.3 Calibration Objectives

No	Simulation Name	Calibration Objectives
1	APF 1	• Head Linear Displacement (x and z) • Head Angular Displacement (y)
2	APF 2	• Head Angular Displacement (y) • C1-C7 Rotational Displacement (y)
3	APF 3	• Head Linear Displacement (x and z) • C1-C7 Angular Displacement (y) • Head Angular Displacement (y)

4. Result & Discussion



Comparison of head C.G kinematics



Comparison of cervical spine y-angular motion

Parameter	Simulation Name			
	APF 1	APF 2	APF 3	Passive
Head x-linear displacement	0.951	0.789	0.927	0.698
Head z-linear displacement	0.347	0.319	0.307	0.331
Head y-angular displacement	0.718	0.627	0.667	0.636
Average of head displacement	**0.672**	**0.578**	**0.634**	**0.555**
C1 y-angular displacement	0.669	0.705	0.698	0.745
C2 y-angular displacement	0.487	0.463	0.464	0.490
C3 y-angular displacement	0.561	0.528	0.557	0.523
C4 y-angular displacement	0.809	0.936	0.899	0.871
C5 y-angular displacement	0.602	0.899	0.747	0.924
C6 y-angular displacement	0.555	0.829	0.674	0.775
C7 y-angular displacement	0.736	0.637	0.712	0.625
Average of cervical spine displacement	**0.631**	**0.714**	**0.679**	**0.708**
Total Average	**0.652**	**0.646**	**0.656**	**0.631**

*highest value

Objective rating results

- The best agreement was obtained by the model that was calibrated against both linear and angular displacement of volunteer head and cervical spine kinematics (APF 3) although the agreement of head kinematics compared to the model that was calibrated against only volunteer head kinematics (APF1) was reduced.
- In the model that was calibrated against head and cervical spine angular motion (APF2), less contraction of cervical muscles were observed. As a result, less neck buckling occurred. Therefore, good agreement was obtained in the cervical spine angular kinematics but not in the head kinematics.

5. Conclusion

- Muscle activation changed the head kinematics by reducing peak linear and angular displacements, as compared to the model without muscle activation.
- The agreement of specific kinematic variables such as head kinematic and cervical spine angular displacement was dependent on the controller calibration objectives.
- The best agreement between volunteer and model was found when the model was calibrated against volunteer linear and angular head displacements and cervical spine angular displacements (APF3).

6. Acknowledgments

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- The authors would like to thank the project members: Astrid Linder, Lotta Jakobsson, Anders Kullgren and Anders Flogård.
- Download ViVA Model at: **http://www.chalmers.se/en/projects/Pages/OpenHBM.aspx**

7. References

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*putra@chalmers.se